

What is claimed is:

1. A method of controlling combustion of a fuel within a combustion chamber of an internal combustion engine, said method comprising:

(a) during a cycle of said internal combustion engine:

- (1) introducing an intake charge into said combustion chamber during an intake event of said cycle, said combustion chamber partially defined by a piston,
- (2) introducing a first quantity of said fuel into said combustion chamber during said intake event or a compression event of said cycle, wherein said first quantity of said fuel and said intake charge are compressed and premixed at or near completion of said compression event,
- (3) directly injecting a second quantity of said fuel into said combustion chamber when said piston is near top dead center,
- (4) burning said fuel in said combustion chamber during a power event of said cycle,
- (5) to a controller, delivering a pre-combustion sensor signal ($P(A)$) determined prior to combustion of

said first quantity of said fuel and a first post-ignition sensor signal ($P(B)$) determined during combustion of said fuel, said sensor signals being indicative of a pressure within said combustion chamber,

- (b) calculating an estimated SOC of said first quantity of said fuel within said combustion chamber from said pre-combustion sensor signal and said first post-ignition sensor signal,
- (c) during a subsequent cycle of said engine, varying an ignition lever if said estimated SOC of said first quantity of said fuel is different than a predetermined target SOC of said first quantity of said fuel.

2. The method of claim 1 wherein said estimated SOC is determined by employing a ratio of said pre-combustion sensor signal and said first post-ignition sensor signal.

3. The method of claim 1 wherein said estimated SOC is determined from the difference between said pre-combustion sensor signal and said first post-ignition sensor signal.

4. The method of claim 1 further comprising delivering to said controller, a second post-

ignition signal ($P(C)$) determined prior to completion of said power event of said cycle, wherein said second post-ignition sensor signal is also employed to calculate said estimated said SOC of said first quantity of said fuel within said combustion chamber.

5. The method of claim 4 wherein said estimated SOC is determined by employing at least one ratio of said pre-combustion sensor signal and at least one of said first post-ignition sensor signal and said second post-ignition sensor signal.

6. The method of claim 5 wherein said first post-ignition sensor signal is determined at a first crank angle, said first crank angle being less than a peak pressure crank angle, said peak pressure crank angle corresponding to a peak cylinder pressure within said combustion chamber during said cycle of said engine.

7. The method of claim 1 wherein said first post-ignition sensor signal is determined at a first crank angle, said first crank angle being greater than a peak pressure crank angle, said peak pressure crank angle corresponding to a peak cylinder pressure within said combustion chamber during said cycle of said engine.

8. The method of claim 6 wherein said

second post-ignition sensor signal is determined at a second crank angle, said second crank angle being greater than said peak pressure crank angle.

9. The method of any one of claims 5 and 8 wherein said ratio is $\frac{P(B)}{P(A)} + \frac{P(C)}{P(A)}$.

10. The method of claim 5 wherein said estimated SOC is directly proportional to said ratio.

11. The method of any one of claims 5, 8 and 9 wherein a first pre-determined constant (K_1) and a second predetermined constant (K_2) are employed to determine said estimated SOC, said estimated SOC being equal to $K_1 P_{ratio} + K_2$.

12. The method of any one of claims 1, 8 and 11 wherein said predetermined target SOC is set by said controller based on an engine speed indicative of a cycle engine speed during said cycle and a boost pressure indicative of an engine load during said cycle.

13. The method of claim 12 wherein said engine speed and said boost pressure are measured.

14. The method of any one of claims 5 and 8 wherein said ratio includes a first ratio and a

second ratio, said first ratio being $\frac{P(B)}{P(A)}$ and
said second ratio being $\frac{P(C)}{P(A)}$, said first ratio
being indicative of a first estimated SOC and said
second ratio being indicative of a second
estimated SOC, said first estimated SOC and said
second estimated SOC being indicative of said
estimated SOC.

15. The method of claim 14 wherein said
first ratio and said second ratio are employed to
calculate said first estimated SOC and said second
estimated SOC, said first estimated SOC and said
second estimated SOC being employed to determine
said estimated SOC.

16. The method of claim 9 wherein an n
number of constants are employed to determine said
estimated SOC, said estimated SOC being equal to
 $K_1(P_{ratio})^{n-1} + K_2(P_{ratio})^{n-2} \dots K_{n-1}(P_{ratio}) + K_n$.

17. The method of claim 1 wherein said
ignition lever is glow plug temperature, said
engine comprising a glow plug in fluid
communication with said combustion chamber.

18. The method of claim 1 wherein said
ignition lever is said quantity of said first
quantity of said fuel.

19. The method of any one of claims 1 through 15 wherein said first quantity of said fuel comprises a first fuel and a pilot fuel and said second quantity of said fuel comprises a second injected fuel, said pilot fuel being more auto-ignitable than said first fuel.

20. The method of claim 19 wherein said pilot fuel is directly injected into said combustion chamber.

21. The method of claim 20 wherein said ignition lever is at least one of pilot fuel quantity, pilot fuel timing and first fuel quantity.

22. The method of claim 21 wherein said first fuel and said second injected fuel have the same composition.

23. The method of claim 22 wherein each of said first fuel and said second injected fuel is a gaseous fuel.

24. The method in claim 23 wherein said gaseous fuel is one of hydrogen and natural gas.

25. The method of claim 24 wherein said first fuel comprises hydrogen and said second injected fuel comprises natural gas.

26. The method in any one of claims 1 through 16 wherein said fuel is a gaseous fuel.

27. The method in claim 26 wherein said gaseous fuel is one of hydrogen and natural gas.

28. The method in claim 27 wherein said gaseous fuel comprises at least one of hydrogen and natural gas.

29. A control apparatus for controlling SOC of a fuel in a combustion chamber of an internal combustion engine, said engine comprising an injector and a manifold for introducing said fuel into said combustion chamber and, said control apparatus comprising:

- (a) a controller, said controller being in communication with an ignition lever capable of adjusting SOC of said fuel within said combustion chamber, and
 - (b) a sensor for directing to said controller a pre-combustion signal and a post-ignition signal, said signals indicative of changes in pressure in the combustion chamber, said sensor in communication with said controller,
- wherein said controller is capable of directing said ignition lever in response to said pre-combustion signal and said post-ignition signal.

30. The control apparatus of claim 29

wherein said sensor is an optical sensor in direct communication with said combustion chamber.

31. The control apparatus of claim 30 wherein said sensor is disposed in a fire deck, said fire deck partially defining said combustion chamber.

32. The control apparatus of claim 31 wherein said sensor is a strain gauge in communication with said fire deck.

33. The control apparatus of claim 29 wherein said fuel comprises a first fuel, a pilot fuel and a second injected fuel, said pilot fuel being more auto-ignitable than said first fuel.

34. The control apparatus of claim 33 wherein said injector is capable of injecting, in addition to said second injected fuel, said pilot fuel and capable of adjusting timing and quantity of said pilot fuel.

35. The control apparatus of any one of claims 33 and 34, wherein said ignition lever is pilot fuel quantity.

36. The control apparatus of claim 34 wherein said ignition lever is said timing of said pilot fuel.

37. The control apparatus of claim 33, wherein a quantity of said first fuel is capable of being adjusted in said manifold, adjusting of said quantity of said first fuel being said ignition lever.

38. The control apparatus of claim 29 wherein ignition lever is a glow plug in fluid communication with said combustion chamber.

39. The control apparatus of claim 33 wherein said pilot fuel is diesel fuel.

40. The control apparatus of claim 33 wherein said first fuel and said second injected fuel have the same composition.

41. The control apparatus of claim 40 wherein each of said first fuel and said second injected fuel is a gaseous fuel.

42. The control apparatus of claim 29 wherein said first fuel and said second fuel are gaseous fuels.

43. The control apparatus of claim 29 wherein said fuel is a gaseous fuel.

44. The control apparatus of claim 43 wherein said gaseous fuel is natural gas.

45. The control apparatus of claim 43 wherein said gaseous fuel is hydrogen.

46. The control apparatus of claim 43 wherein said gaseous fuel comprises at least one of hydrogen and natural gas.

47. A method of controlling combustion of a main fuel within a combustion chamber of an internal combustion engine, said method comprising:

- (a) during a cycle of said internal combustion engine:
 - (1) introducing an intake charge into said combustion chamber during an intake event of said cycle,
 - (2) introducing a first quantity of said main fuel into said combustion chamber during said intake event or a compression event of said cycle,
 - (3) introducing a first quantity of a pilot fuel into said combustion chamber at a pilot timing during said intake event or said compression event of said engine, wherein said first quantity of said main fuel, said first quantity of said pilot fuel and said intake charge are compressed and premixed into an auto-ignitable fuel/air charge at or near completion of

- said compression event, said pilot fuel is more auto-ignitable than said main fuel,
- (4) directly injecting a second quantity of said main fuel into said combustion chamber when a piston partially defining said combustion chamber is near top dead center,
 - (5) to a controller, delivering a pre-combustion sensor signal ($P(A)$) determined prior to combustion of said auto-ignitable fuel/air charge and at least one post-ignition sensor signal determined during combustion of said main fuel, said sensor signals being indicative of a pressure within said combustion chamber,
- (b) calculating at least one ratio (P_{ratio}) from said pre-combustion sensor signal and said post-ignition sensor signal, said at least one ratio being indicative of an estimated SOC of said auto-ignitable fuel/air charge within said combustion chamber,
- (c) during a subsequent cycle of said engine, varying at least one of said first quantity of said pilot fuel, said pilot timing, said first quantity of said main fuel, if said estimated SOC of

said auto-ignitable fuel/air charge is different than a predetermined target SOC of said auto-ignitable fuel/air charge.

48. The method of claim 47 wherein two post-ignition sensor signals are delivered to said controller, said two post-ignition sensor signals being a first post-ignition sensor signal ($P(B)$) and a second post-ignition sensor signal ($P(C)$).

49. The method of claim 48 wherein said first post-ignition sensor signal is determined at a first crank angle, said first crank angle being less than a peak pressure crank angle, said peak pressure crank angle corresponding to a peak cylinder pressure within said combustion chamber during said cycle of said engine.

50. The method of claim 49 wherein said second post-ignition sensor signal is determined at a second crank angle, said second crank angle being greater than said peak pressure crank angle.

51. The method of any one of claims 48 and 50 wherein said ratio is $\frac{P(B)}{P(A)} + \frac{P(C)}{P(A)}$.

52. The method of claim 51 further comprising calculating said estimated SOC from said ratio.

53. The method of claim 52 wherein a first pre-determined constant (K_1) and a second predetermined constant (K_2) are employed to determine said estimated SOC, said estimated SOC being equal to $K_1 P_{ratio} + K_2$.

54. The method of claim 52 wherein an n number of constants are employed to determine said estimated SOC, said estimated SOC being equal to $K_1 (P_{ratio})^{n-1} + K_2 (P_{ratio})^{n-2} \dots K_{n-1} (P_{ratio}) + K_n$.

55. The method of claim 50 wherein said ratio includes a first ratio and a second ratio, said first ratio being $\frac{P(B)}{P(A)}$ and said second ratio being $\frac{P(C)}{P(A)}$, said first ratio being indicative of a first estimated SOC and said second ratio being indicative of a second estimated SOC, said first estimated SOC and said second estimated SOC being indicative of said estimated SOC.

56. The method in any one of claims 49 through 55 wherein said main fuel is a gaseous fuel.

57. The method in claim 56 wherein said gaseous fuel is one of hydrogen and natural gas.

58. The method in claim 57 wherein said gaseous fuel comprises at least one of hydrogen and natural gas.